

MULTIMEDIA



UNIVERSITY

STUDENT ID NO

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MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2019/2020

EME4016 – HEAT TRANSFER

(ME)

25 OCTOBER 2019

3.00 p.m. - 5.00 p.m.

(2 Hours)

INSTRUCTIONS TO STUDENT

1. This Question Paper consists of five pages including the cover page.
2. Answer ALL four questions. Each question carries 25 marks and the distribution of the marks for each question is given in brackets [].
3. Write all your answers in the Answer Booklet provided.

Question 1

- (a) Steam at saturation temperature $100\text{ }^{\circ}\text{C}$ is condensing in a stainless steel pipe where the inner radius of the pipe, $r_i = 2\text{ cm}$ and the thickness of the wall is 0.30 cm . The outer surface of the pipe is exposed to ambient air at $15\text{ }^{\circ}\text{C}$. The inside and outside heat transfer coefficients are $h_i = 2,000\text{ W/m}^2\cdot\text{K}$ and $h_o = 10\text{ W/m}^2\cdot\text{K}$ respectively, while the thermal conductivity of the pipe is $k = 20\text{ W/m}\cdot\text{K}$. Assume steady-state one-dimensional heat conduction.

- (i) Show the thermal circuit representing the steady-state heat transfer by labeling all elements, nodes, and heat rate. Leave your answer in symbolic form. **[6 marks]**

- (ii) Determine the rate of heat loss per unit length of the pipe .

[7 marks]

- (iii) *Explain* critical insulation radius in the context of thermal insulation for cylindrical pipe. If a uniform layer of gypsum ($k_g = 0.25\text{ W/m}\cdot\text{K}$) is applied to the outer surface of the pipe for insulation purpose, *determine* its critical insulation thickness in mm.

[6 marks]

- (b) A 4-cm thick large steel plate which is initially at a uniform temperature of $25\text{ }^{\circ}\text{C}$ passes through an oven at $800\text{ }^{\circ}\text{C}$. Take the heat transfer coefficient in the oven to be $h = 30\text{ W/m}^2\cdot^{\circ}\text{C}$, and the properties of the steel plate as: $\rho = 7832\text{ kg/m}^3$, $c_p = 434\text{ J/kg}\cdot^{\circ}\text{C}$ and $k = 63.9\text{ W/m}\cdot^{\circ}\text{C}$. Estimate the time in minutes required for the plate temperature to reach $500\text{ }^{\circ}\text{C}$, by using lumped capacitance method.

[6 marks]

Continued...

Question 2

A silicon chip is cooled by routing air at mass flow rate $\dot{m} = 5 \times 10^{-6}$ kg/s and inlet temperature, $T_i = 15^\circ\text{C}$ through a circular tube of inner diameter $D = 750 \mu\text{m}$, and length

$L = 20$ mm, machined at the back of the device. Assume that the entire surface of tube is maintained at *constant temperature* of 80°C , and the flow in the tube is *fully developed*.

Take air properties as:

$\rho = 1.164 \text{ kg/m}^3$, $k = 0.02588 \text{ W/m}\cdot^\circ\text{C}$, $\nu = 1.608 \times 10^{-5} \text{ m}^2/\text{s}$, $\text{Pr} = 0.7282$ and $c_p = 1007 \text{ J/kg}\cdot\text{K}$.

- (a) Find the Reynolds number of the air flow. [5 marks]
- (b) Determine the heat transfer coefficient for the air flow in the tube. [4 marks]
- (c) Determine the air outlet temperature. [7 marks]
- (d) Determine the chip power dissipation, assuming that the heat loss to the surrounding is negligible. [4 marks]
- (e) Sketch the air temperature along the axial direction of the tube clearly along with the tube surface temperature. Comment on the temperature profiles.

[5 marks]

Note: Nusselt number correlations for fully developed flow in tube are :

1. $Nu_D = 0.023 \text{Re}_D^{0.8} \text{Pr}^n$, $n = 0.4$ for *heating* and 0.3 for *cooling*, turbulent flow.
2. $Nu_D = 4.36$ for uniform surface heat flux, laminar flow.
3. $Nu_D = 3.66$ for uniform surface temperature, laminar flow.

Continued...

Question 3

A chemical at 20 °C enters the annulus of a double-pipe counter flow heat exchanger at a rate of 3.5 kg/s while hot water at 98 °C enters through the 3-cm diameter tube at a mass flow rate of 3 kg/s. The outlet temperature of the chemical is 45 °C, and the overall heat transfer coefficient is 1250 W/m²·°C. Consider the specific heats for the hot water and chemical as 4180 J/kg·°C, and 3800 J/kg·°C respectively.

- (a) Find the outlet temperature for hot water. **[5 marks]**
- (b) Determine the log mean temperature difference of the heat exchange. **[6 marks]**
- (c) How long must the tube be made ? **[6 marks]**
- (d) For the same overall heat transfer coefficients, inlet temperatures and outlet temperatures for both hot and cold streams, an engineer intends to compare the surface area required for parallel flow and counterflow arrangements. What is the ratio of the surface area for counterflow arrangement to that for parallel plate arrangement? **[8 marks]**

Continued...

Question 4

- (a) Construct the thermal radiation network for radiation exchange between two gray surfaces, 1 and 2, labelling all nodes and resistances. State the equation to calculate the heat transfer between them. **[8 marks]**

- (b) During winter time, a room with dimensions 2.5 m by 2.5 m by 2.5 m is heated through the floor by maintaining it at a uniform temperature T_1 , while the four walls and ceiling are at $T_2 = 270$ K. Given that the floor has an emissivity ε_1 of 0.8, and the walls and the ceiling have an emissivity ε_2 of 0.5.

- (i) If the rate of heat loss through the floor due to radiation is 800 W, find the floor temperature, T_1 . **[7 marks]**

Note: You may find part (a) useful for part (i).

- (ii) If the ceiling has a temperature T_3 , while T_1 , T_2 , and T_3 are known and they are not the same, *state the necessary steps and equations in terms of symbols*, to solve the heat transfer from the floor due to radiation, assuming that the view factor for the two aligned parallel plates are given. In this part, you may use subscripts 1, 2 and 3 to denote floor, walls, and ceiling respectively. **[10 marks]**

Note: Take the Stefan-Boltzmann constant to be $5.67 \times 10^{-8} \text{ W/m}^2 \cdot \text{K}^4$.

End of Paper.